THE INTERRELATIONSHIPS OF GRAIN YIELD, STOMATAL LENGTH, AND SOIL DROUGHT IN WHEAT VARIETIES

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INTRODUCTION

The problem of drought and the production of wheat varieties resistant to it has been a major project of the Department of Field Crops, University of Alberta, for many years. Despite the volume of work done both on this continent and abroad a mutually satisfactory solution of common difficulties has not yet been propounded. Chief among these difficulties is the inability to select readily plants whose progeny will give the highest return of grain under conditions of limited soil moisture.

The workers in this department who initiated the project realized that progress in breeding for drought resistance would be extremely slow until such time as the relationships of various plant characters to yield under dry conditions were understood. Accordingly many studies were undertaken with this end in view and substantial progress has been made. The most promising relationships, for use of the plant breeder, were those established between stomatal length and yield, and between protein content and yield. Another promising relationship was that established between reaction to soil drought and

yield by workers at the Dominion Experimental Station, Swift Current, Saskatchewan. These studies indicate that, in breeding wheats with high yielding capacity for drought areas, it would be possible to increase the general yield level of the hybrid populations by selecting on the basis of stomatal length, protein content, or reaction to soil drought. The relative value of the three characters for this purpose cannot be determined, however, as the studies were made on different lots of material.

The present investigation was designed to provide additional information on these relationships and to assess the relative value of each in breeding wheats with superior drought resistance. Accordingly, the three characters, stomatal length, protein content, and reaction to soil drought were all studied in relation to yield with the same varieties and hybrid lines. In addition the relationships of certain other characters, such as plant height and time of maturity, were investigated.

A general outline of the experiments conducted and the plan followed in presenting the results of these will clarify the organization of this thesis. Six experiments were conducted. Experiments 1 and 2 were greenhouse trials in which the relation between seedling leaf stomatal length and soil drought reaction was studied. Experiments 3 and 4 were field tests conducted at Edmonton and Swift Current respectively; data were obtained on yield, time of maturity, height, protein content, and 1000 kernel weight. In addition Experiment 4 was

used for a study of the relation between seedling and flag leaf stomatal lengths. Experiment 5 was a greenhouse test in which the plants were grown under limited soil moisture conditions and the effect of this upon the seedling - flag leaf stomatal length relationship was determined. Experiment 6 was planned for the same purpose as Experiments 1 and 2 but data on stomatal length only were obtained.

The results obtained from these studies are presented in four sections:

1. Reaction to soil drought.
2. Agronomic characters.
3. Stomatal lengths on seedling and flag leaves.
4. The interrelationships of the various characters.

LITERATURE REVIEW

This review is divided into three main sections which cover in turn the literature on stomatal length, reaction to soil drought, and plant character relationships in the cereal crops.

Stomatal length was early demonstrated to be a varietal characteristic. Kolkunov (26) found that there was a range of from 64 to 96 microns in the eight wheat varieties he examined. In a study of sixteen pure lines of oats Yakushkina and Vavilov (57) found stomatal length to be a heritable character. Later Kolkunov (29) examined four pure lines of Beloturka wheat and found it possible to identify them by their relative stomatal lengths. Heuser (21) studied stomatal length on terminal and sub-terminal leaves of three wheat varieties and recorded varietal differences. Birdsall (2) concluded that significant differences in stomatal length of wheat varieties could be expected when either the seedling, sub-terminal, or terminal leaves were compared for this character.

The character of stomatal length is variable between the leaves of the same plant. Zalenski (61) concluded that stomatal length decreased with increasing height of insertion of the leaf within a plant. Yapp (58) supported this conclusion in independent parallel studies. Salisbury (45) found that, although such was generally the case, when plants

developed in a humid atmosphere the gradient tended to disappear. Heuser (20) found that such a gradient occurred and Birdsall's data (2) shows that it existed in his material.

Environment exerts a pronounced influence on the stomatal size of all leaves developed during the later stages of growth. Most studies have been concerned with the flag or terminal leaves. Kolkunov (27), in an investigation with beets, found that the most resistant plants in fields affected by drought had the smallest cells in roots and leaves. The work done by Heuser (21) with three wheat varieties grown at five locations also demonstrated an environmental influence on cell size. Eberhardt (11) and Lebedintsev (31) examined plants grown under various levels of humidity and found that lower humidities induced greater xeromorphy of structure. The works of Heuser (20), Rippel (44), Frey (13), Kokin (25), Tumanov (50), Van de Roovaart and Fuller (51), Birdsall (2), and Whiteside (56) all show that stomata were more numerous and smaller when plants were grown with limited soil moisture. Some workers report results which do not agree with the majority; Weiss (54) worked with a number of species and Kiesselbach (24) with corn varieties and neither found any evidence of environmental influences. Sande-Bakhuyzen (46) found that the seedling leaves of wheat showed no significant variation due to external conditions when compared on the basis of stomatal length.

Stomatal length has been correlated with other plant characters by several workers. In a wet year Kolkunov (28)

found the high yielding corn varieties to be large celled while the reverse was found in a dry year. He reported the same findings for wheat when grown at various moisture levels in pot cultures, (29). In another case Kolkunov (28) reported short stomata to be associated with earliness. Scheibe (47) concluded that shorter stomata and greater drought resistance were related. In a study of spring and winter wheats Pavlov (39) found earliness, shorter stomata, and increased suction pressure, with few exceptions, to be associated with increased drought resistance. Birdsall (2) reported that stomatal length was negatively correlated with yield and positively correlated with protein content in wheat. Yakushkina and Vavilov (57) failed to find any relation between cell size and length of the growing period, tillering ability, disease resistance, or yield in sixteen oat lines.

Soil drought and the relative ability of plants to survive it has been studied by numerous workers. Plant ecologists and physiologists have studied the adaptations of species and their relative abilities for survival when grown under dry conditions. Of more immediate interest are those few papers which have dealt with varietal resistance to soil drought, especially those concerned with crop plants.

Maximov (34) concluded that "the capacity of enduring prolonged wilting is one of the most important of the characters the sum total of which determines drought resistance in plants". Under Maximov's direction Tumanov (50) subjected eight wheat varieties to two weeks' drought at the shooting

stage. On the basis of plants killed he recorded survivals ranging from 23 to 94 per cent. Kondo (30), using a similar treatment, recorded differences in survival for varieties within the crops mustard, sunflower, soybean, safflower, and flax. Sugar beet varieties were tested by Orlovsky and Oumanska (38) and they found varietal differences when the tests were made at the two leaf stage. Orlovsky (37) reported further studies with sugar beets in which he selected surviving plants within a variety and found their progeny to register survivals 12 per cent higher than those of the parent variety. Perepeliuc (40) classified Rumanian wheats on the basis of Tumanov's method, using a ten day treatment, and found distinct varietal differences. Aamodt and Johnston (1) found Reward and Caesium to differ markedly in regard to survival following soil drought, Caesium survived while Reward did not. In an attempt to utilize this varietal characteristic Platt and Darroch (43) conducted a series of experiments with wheat varieties and lines; in all cases highly significant varietal differences were recorded despite a significant variety by test interaction.

The survival of plants following a period of soil drought may be related to other plant characters. There have been, apparently, only a few attempts to establish definite relationships. Tumanov (50) stated that, in general, his results agreed with field reaction. Orlovsky (37) found that the varieties of sugar beets showing highest survival gave the highest yields of roots and had the lowest sugar contents.

Yield and survival were positively correlated in the experiments reported by Platt and Darroch (43).

There have been a number of studies in which the relationship between yield and such characters as maturity, height, protein content, and 1000 kernel weight has been studied. The relation between yield and protein content isessentially negative, as reported by Clark and Hooker (7), Clark, et al (6), Waldron (53), Malloch and Newton (33), and Neatby and McCalla (36). Significant positive correlations were reported by Clark and Hooker (7), and Clark, et al (6) while in some cases no relationship was found by Clark, et al (6) and Neatby and McCalla (36). Yield and earliness were found to be negatively correlated by Goulden and Elders (16), Hayes, et al (18), Bridgford and Hayes (3), Goulden and Neatby (17), Immer and Stevenson (23), Immer and Ausemus (22), Waldron (53), Moussouros and Papadopoulos (35), and Torrie (49). A positive relationship has been reported by Clark and Hooker (7), Bridgford and Hayes (3), and Goulden and Elders (16) while no association was found by Clark and Hooker (7), Hayes, et al (18), and Torrie (49) between these two characters. Plant height and yield was found to be positively correlated by Clark and Hooker (7), Hayes, et al (18), Goulden and Neatby (17), and Bridgford and Hayes (3), while Immer and Stevenson (23), Waldron (53), and Torrie (49) found no association. Height and maturity correlations have shown variability: Immer and Stevenson (23), Hayes, et al (18), and Torrie (49) reported positive correlations while Goulden

and Neatby (17), and Bridgford and Hayes (3) obtained negative correlations and Clark and Hooker (7) no association. Maturity and protein content were found positively correlated by Clark, et al (6), and Waldron (53) but instances of no association were also given by Clark, et al (6). Weight per 1000 kernels was found positively correlated with yield by Goulden and Neatby (17), Bridgford and Hayes (3), Waldron (53), and Laude (32). Maturity and kernel weight were found negatively correlated by Goulden and Neatby (17) and Waldron (53) while Bridgford and Hayes (3) report a positive relationship. Height and kernel weight were positively correlated, Goulden and Neatby (17), or not associated, Bridgford and Hayes (3).

MATERIALS AND METHODS

Material

Twenty-seven named varieties and four hybrid lines of spring wheat - a total of thirty-one - were used in each experiment reported on in this thesis. Over half of the varieties have been or are being grown commercially in Western Canada; the remainder have been or are being grown commercially in the spring wheat area of the United States, Russia, Australia, and other important wheat producing countries. Two of the hybrid lines - S-615 and S-633 - were secured from Dr. O. H. Frankel, Wheat Breeding Institute, Christchurch, New Zealand, by the Cereal Division, Dominion Experimental Station, Swift Current, Saskatchewan, for use as parental material in their wheat breeding program (42). The other two hybrid lines were developed as a direct result of the intensive breeding program conducted by this department; these hybrids, I-28-60 x Milturum (H-29-35) and Caesium x Marquis (H-37-30), will be cited in this thesis by their respective hybrid numbers only.

Experimental Methods

The methods used in these studies have been described by previous workers and need only be briefly outlined.

Birdsall (2) has described a rapid method of measuring

stomatal lengths of wheat leaves. He used an ocular screw-micrometer, magnification approximately 15X, with an 8X objective and secured a direct reading of stomatal length in microns. He found it most satisfactory to place the fresh leaves in water and leave them in a cool chamber for a time to ensure complete closure of the stomata. All his measurements were made on the lower surfaces of the leaves with reflected light, length being determined as length of the guard cells. Birdsall concluded that, by measuring ten stomata per leaf on each of five leaves within a variety, sufficiently accurate estimates of relative stomatal lengths could be secured.

This method was utilized in the present study with this modification. A trans-leaf sample was taken within 1.5 to 2 inches of the leaf tip whereas Birdsall took a trans-leaf sample near the base. The leaf tip is the region where differentiation, maturation, and chlorophyll synthesis are first completed (10), and would therefore seem to be the more suitable region upon which to base varietal comparisons.

The method of Platt and Darroch (43) was used to determine varietal reactions to soil drought. By the use of one-gallon glazed crocks, equal portions of air dried soil, a uniform number of plants, a uniform supply of moisture, and a sawdust mulch to control evaporation, they obtained highly significant varietal differences in replicated experiments. A period of drought, of two weeks duration commencing from the time of permanent wilting, was the usual treatment. At

this time the plants were in the three to four leaf stage.

These techniques, together with the usual methods of conducting field trials, were utilized in these studies. Further modifications of any one of them will be outlined where they were specifically applied.

Statistical Methods

The experimental design utilized in all phases of this study was the Balanced Lattice, of the type $v = p^2 - p + 1 = 31$ varieties. This design permits of six variety replicates randomized within 31 incomplete blocks. Yates (59) has described this type of Randomized Incomplete Block lay-out.

Goulden (14) and Weiss and Cox (55) have fully outlined the analysis of variance as applied to the data from the experiments herein reported. It should be pointed out, however, that Yates (60) has recently outlined a method for the recovery of inter-block information in these designs. The original method has been followed because of greater simplicity and because it could be subjected to a direct test of significance.

The necessary difference was calculated by the method of Weiss and Cox (55). The value of t at the 5 per cent point for residual degrees of freedom was determined from Appendix Table I in Hayes and Immer (19). The standard error of a difference, calculated from the residual variance of an experiment, multiplied by the value of t gave the

difference necessary for significance.

Cornish (8) has given an example of covariance analysis as applied to Balanced Lattice designs. The test of significance outlined by Goulden (15) was applied to the corrected variance of the dependent variable.

Hayes and Immer (19) suggest that where percentage data are used, if the range is between 25 and 75 per cent, no transformation need be applied. The necessity of applying a transformation to any percentage data encountered in these studies was considered with this range in mind. No such transformation was found to be necessary.

A summary of literature revealed that no method of determining the significance of variety x experiment interaction variance in Balanced Lattice designs had appeared in print. Since it is rather useful when comparing the results from duplicate or more experiments an appropriate method was derived. The grand total for all experiments is used to derive an aggregate correction factor; the sum of squares for experiments is secured by summating the squared totals of each, dividing by the number of plots per experiment, and subtracting the aggregate correction factor. The total sum of squares is arrived at in the usual manner using the grand total of $\underline{S}x^2$ minus the aggregate correction factor. New values of the quantities (pTuv - $\underline{S}$uv)[x], (14, p. 29), for the

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[x] $\underline{S}$ replaces the Greek letter 'big sigma' used for "summation of".

calculation of the variety means are determined by summating these quantities for each variety over all individual experiments. Mean variety sum of squares is calculated by summating $(pTuv - \underline{S}uv)^2$ and dividing by the aggregate number of plots. The sums of squares for incomplete blocks and residual are derived by addition of these quantities as they appear in the individual analyses. The sum of squares formed by adding the individual experiment variety sums of squares contains the mean variety sum of squares plus the interaction sum of squares, the latter is then derived by difference. The degrees of freedom for incomplete blocks are the sum of those appearing in the individual analyses, the rest are derived in the usual manner. These sums of squares and the appropriate degrees of freedom are set up in an analysis of variance table and the usual computations carried out. The author is indebted to Dr. C. H. Goulden, Dominion Rust Research Laboratory, Winnipeg, Manitoba, for certain suggestions and criticisms while developing this method.

RESULTS

The data on each character or group of characters are presented in separate sections of this paper. The method used in obtaining the results and a brief discussion of the significance of the results obtained are included with the data on each character.

Reaction to Soil Drought

Methods

Experiment 1 was conducted in the greenhouses of this institution during the period from January to March 1942. In this experiment seedling leaf stomatal length and drought survival of the 31 varieties were studied. The soil used was an Edmonton loam with an approximate wilting point of 12 per cent. Equal amounts of this soil, screened, well mixed, and of known moisture content, were weighed into one-gallon glazed crocks. Twenty plants were established in each crock. A moisture content of 25 per cent was maintained until the twelfth day after seeding, when a sawdust mulch (125 grams) was applied; no further moisture was then added. Permanent wilting occurred 14 days after mulching and an interval of 36 days elapsed after wilting before the mulch was removed and watering resumed. Survival notes were taken ten days after the application of moisture had been resumed.

Experiment 2 was conducted in the greenhouses of the Dominion Experimental Station, Swift Current, during May and June 1942. This experiment was similar to Experiment 1 in purpose and in most details. A Haverhill loam with a 9 per cent wilting point was used. The moisture content was kept at 31 per cent for the first 11 days after seeding; then the sawdust mulch was applied and watering was discontinued. Permanent wilting occurred 12 days later and moisture was again applied 13 days after wilting. The notes on survival were recorded six days from the recommencement of watering.

With both experiments survival notes were taken by scoring the individual plants. A numerical index, ranging from zero for a dead plant to four for one which showed little foliar loss, was found to be satisfactory. The replicate percentage values, as used in the analyses of variance, were obtained by the use of the formula:

$$\frac{\text{Total crock score}}{\text{Number of plants}} \times 25 = \text{percentage survival.}$$

Results

The data on the soil drought reactions of the 31 varieties are presented in Table I. The percentage survivals are given for the individual experiments, the varieties being arranged in order of decreasing mean survival. The results of the analyses of variance for the individual experiments are presented in Table II, and the results for the multiple variance analysis in Table III.

Figure 1 shows the extremes of damage found in Experiment 2. Prior to photographing the dead leafage was removed to allow for greater clarity of detail.

Variety variance is highly significant in each of the three variance analyses. The mean range of 36 per cent, four times the necessary difference, demonstrates the magnitude of the varietal differences.

The significant variety x experiment interaction indicates that not all varieties reacted alike in the two experiments. In general it can be said that the mean variety ranking agreed with that in the individual experiments; variety variance significantly exceeded interaction variance, giving an F value of 3.75. The fact that opposite conditions of humidity, light intensity, and temperature were encountered in these two experiments may account, in part, for the interaction. Platt and Darroch (43) reported a similar interaction effect in earlier studies.

Figure 1 - From left to right the contrasting survivals of Bena, Cross Seven, Garnet, and Reward are 70, 72, 21, and 28 per cent respectively. Experiment 2.

Table I

Percentage survival of 31 wheat varieties when exposed to soil drought in Experiments 1 and 2

Variety	Percentage Survival		
	Experiment		Mean
	1	2	
Cross Seven	62.2	71.4	66.8
Kenya	54.3	69.0	61.7
Bena	48.1	72.8	60.4
Milturum .0321	57.2	63.5	60.3
Nabawa	48.6	68.6	58.6
Bunyip	55.7	60.8	58.2
Thatcher	51.4	59.9	55.6
Red Bobs	46.6	63.3	55.0
Dicklow	49.3	60.3	54.9
Lutescens .062	53.1	56.6	54.8
Ceres	47.3	58.6	53.0
Apex	50.9	53.6	52.2
S-615	49.2	54.6	51.9
Baart	42.2	61.2	51.7
S-633	49.5	53.8	51.7
H-37-30	53.4	46.4	49.9
Hard Federation	42.4	57.2	49.8
Canus	52.5	46.3	49.4
Red Fife	48.8	49.2	49.0
Caesium	45.9	50.5	48.2
Marquis	47.8	47.3	47.5
Renfrew	45.5	48.8	47.1
Erythrospermum .0341	43.2	50.0	46.6
Hope	41.6	48.4	45.0
H-29-35	47.4	39.3	43.4
Comet	43.7	42.0	43.1
Regent 975.6	39.0	46.5	42.7
Sikora	35.4	49.0	42.2
Renown	36.0	34.6	35.3
Reward	37.9	27.2	32.5
Garnet	32.2	29.4	30.8
General Mean	47.0	52.9	50.0
Necessary Difference	9.6	9.6	8.1

Table II

Results of the analyses of variance of the
percentage survival values for
Experiments 1 and 2

Variance due to	D.F.	Mean squares for	
		Experiment 1	Experiment 2
Varieties	30	233.08$^{\times\times}$	662.70$^{\times\times}$
Incomplete blocks	30	147.42$^{\times\times}$	439.64$^{\times\times}$
Residual	125	59.75	60.54

$^{\times\times}$ Exceeds the 1% point

Table III

Results of the multiple analysis of variance
of the percentage survival values
for Experiments 1 and 2

Variance due to	D.F.	Mean squares	F value
Experiments	1	3230.84	53.72$^{\times\times}$
Varieties	30	707.07	3.75$^{\times\times}$
Varieties x experiments	30	188.72	3.14$^{\times\times}$
Incomplete blocks	60	293.53	4.88$^{\times\times}$
Residual	250	60.14	
Total	371		

$^{\times\times}$ Exceeds the 1% point

Available Soil Moisture

Methods

In Experiment 1 the moisture content of the soil in each crock was noted at the beginning and end of the drought period. Thus it was possible to determine, by difference, the amount of water removed by the plants during the entire drought period. The reductions, in grams of water per crock, were treated statistically by an analysis of variance.

Comparable data were obtained for Experiment 2.

Results

The results of the analyses of variance are presented in Table IV. In Experiment 1 the soil moisture content was reduced from 25 per cent to 14.4 per cent, amounting to a decrease of 354 grams of water. There was a greater amount of moisture used in Experiment 2 and the moisture content dropped from 30.9 per cent to 9.4 per cent; this represents a loss of 882 grams of water. The mean values only are presented for each experiment because tabulation of variety values was not warranted.

Variety variance did not significantly exceed residual variance in either experiment. The incomplete blocks accounted for the major portion of the total variation in each experiment.

Briggs and Shantz (4) have reported that they found no evidence of a differential varietal capacity for obtaining

soil moisture. Further they concluded that the amount of moisture unavailable depended solely upon soil type. Both of these statements hold true in the present experiments. Therefore these results demonstrate that survival differences are not due to any varietal differences in the amount of water removed from the soil during a period of drought.

Table IV

Results of the analyses of variance of the weight of water, in grams, removed during the periods of drought in Experiments 1 and 2

Variance due to	D.F.	Mean squares for	
		Experiment 1	Experiment 2
Varieties	30	205.2	335.4
Incomplete blocks	30	1022.2$^{\boxtimes\boxtimes}$	10794.1$^{\boxtimes\boxtimes}$
Residual	125	205.4	327.5

$^{\boxtimes\boxtimes}$ Exceeds the 1% point

Agronomic Results

Methods

Experiment 3 was conducted at Edmonton in the experimental field maintained by this department. It consisted of single row plots 18.5 feet long, the rows being spaced one foot apart. Notes on days to head, days to mature, and plant height were recorded in the field. Yield per 16.5 foot row was recorded and treated by analysis of variance. Protein content and 1000 kernel weight were determined from a composite sample of each variety.

A similar experiment, Experiment 4, was grown by the Cereal Division, Dominion Experimental Station, Swift Current. The characters listed above for Experiment 3 were also recorded for this experiment.

Results

The data secured in each experiment, together with the variety mean values, are presented in Table V. Analyses of variance of the yield data, in grams per plot, are presented in Table VI for the individual experiments; a multiple analysis of these data is presented in Table VII. The inter-experiment correlations for the other five characters are presented in Table VIII.

Variety variance for the yields at Edmonton and at Swift Current is highly significant (Table VI). The presence of a significant interaction (Table VII) between the yields from

the two tests is sufficient to render mean variety variance insignificant when tested against interaction variance; an F value of 1.58 was obtained. Yields were very high at both points with a mean of 52.4 bushels per acre being recorded for all varieties grown in the two experiments.

The data on days to head and to mature, height, protein content, and 1000 kernel weight are presented without statistical treatment. Varietal differences were recorded for all of these characters and these differences, undoubtedly, would be significant in all cases. The high values of the correlations reported in Table VIII show a very close agreement between the values recorded in the individual experiments.

Table V

Results for yield in bushels, protein content in per cent, days to head, days to mature, plant height in inches, and 1000 kernel weight in grams from Experiments 3 and 4

Variety	Yield in Bushels Experiment 3	Yield in Bushels Experiment 4	Yield in Bushels Mean	Protein in Per Cent Experiment 3	Protein in Per Cent Experiment 4	Protein in Per Cent Mean
Canus	87.1	48.6	67.8	13.0	13.5	13.2
Caesium	88.5	46.3	67.4	13.9	13.6	13.8
H-37-30	82.7	48.1	65.4	14.1	13.9	14.0
Erythrospermum .0341	77.1	46.2	61.6	13.7	13.1	13.4
H-29-35	78.4	44.2	61.3	13.7	13.8	13.8
Nabawa	77.9	41.3	59.6	12.1	11.6	11.8
Red Fife	74.3	43.4	58.9	14.5	14.7	14.6
Baart	62.0	51.8	56.9	14.2	12.8	13.5
Bena	58.2	55.1	56.7	11.1	11.8	11.4
Thatcher	68.3	42.8	55.5	13.5	13.0	13.2
Red Bobs	68.0	40.6	54.3	13.5	12.6	13.0
S-615	64.3	44.0	54.2	14.6	14.4	14.5
Ceres	67.1	40.1	53.6	14.1	13.4	13.8
Renfrew	61.4	45.2	53.3	13.2	12.6	12.9
Milturum .0321	62.6	43.0	52.8	13.6	12.7	13.2
Hard Federation	58.3	47.1	52.7	11.6	11.7	11.6
Bunyip	67.6	34.2	50.9	12.6	12.8	12.7
Kenya	55.8	45.8	50.8	13.6	12.3	13.0
Comet	62.7	38.6	50.7	12.6	12.2	12.4
Lutescens .062	56.9	42.5	49.7	13.6	13.7	13.6
Dicklow	46.3	53.0	49.6	11.3	12.1	11.7
Sikora	60.3	36.5	48.4	13.3	13.2	13.2
Garnet	58.5	36.7	47.6	13.5	13.4	13.4
Marquis	55.1	40.2	47.6	14.5	13.9	14.2
Regent 975.6	57.5	41.0	47.6	15.2	13.7	14.4
S-633	49.1	44.6	46.9	13.5	13.6	13.6
Apex	51.3	41.4	46.4	13.7	14.0	13.8
Hope	57.0	31.8	44.4	14.1	13.6	13.8
Cross Seven	40.8	43.4	42.1	13.6	13.5	13.6
Reward	38.9	33.6	36.3	15.4	14.2	14.8
Renown	39.3	30.3	34.8	14.5	14.2	14.4
General Mean	62.3	42.6	52.4	13.5	13.2	13.4
Necessary Difference	12.6	6.2	11.9	--	--	--

Table V - Cont'd.

Results for yield in bushels, protein content in per cent, days to head, days to mature, plant height in inches, and 1000 kernel weight in grams from Experiments 3 and 4

Variety	Days to Head			Days to Mature		
	Experiment 3	Experiment 4	Mean	Experiment 3	Experiment 4	Mean
Canus	73.2	71.3	72.3	133.4	123.7	128.6
Caesium	74.6	73.3	73.9	132.5	125.2	128.8
H-37-30	75.4	73.2	74.3	132.4	124.5	128.4
Erythrospermum .0341	75.1	70.8	73.0	134.7	123.6	129.1
H-29-35	76.0	73.1	74.5	131.7	124.6	128.2
Nabawa	74.0	70.8	72.4	122.8	123.8	123.3
Red Fife	78.1	75.3	76.7	131.2	126.0	128.6
Baart	73.4	70.0	71.6	129.3	123.6	126.4
Bena	78.4	74.7	76.5	137.4	125.8	131.6
Thatcher	71.0	67.5	69.2	120.8	117.3	119.0
Red Bobs	70.7	67.5	69.1	121.2	116.4	118.8
S-615	76.2	70.7	73.4	133.1	122.6	127.8
Ceres	72.4	68.8	70.6	123.6	121.2	122.4
Renfrew	77.6	73.5	75.5	132.7	124.3	128.5
Milturum .0321	82.2	80.4	81.3	132.2	126.9	129.6
Hard Federation	76.7	72.4	74.5	130.6	123.7	127.2
Bunyip	72.4	67.5	69.9	122.2	117.6	119.9
Kenya	77.0	72.7	74.8	134.8	124.9	129.8
Comet	70.9	67.5	69.2	124.2	119.8	122.0
Lutescens .062	80.1	76.0	78.0	135.1	125.7	130.4
Dicklow	82.8	76.5	79.6	140.6	126.0	133.3
Sikora	71.1	66.0	68.5	115.8	107.0	111.4
Garnet	70.2	65.2	67.7	115.7	107.9	111.8
Marquis	73.8	70.6	72.2	131.4	122.9	127.2
Regent 975.6	69.7	65.4	67.6	119.2	110.4	114.8
S-633	77.1	71.2	74.1	135.3	123.7	129.5
Apex	71.8	68.1	69.9	123.2	118.3	120.8
Hope	71.7	69.3	70.5	124.8	121.0	122.9
Cross Seven	85.7	82.0	83.8	147.4	132.3	139.8
Reward	69.2	63.4	66.3	117.7	109.2	113.4
Renown	71.6	65.1	68.4	125.5	112.4	119.0
General Mean	74.8	71.0	72.9	128.8	121.1	124.9

Table V - Cont'd.

Results for yield in bushels, protein content in per cent, days to head, days to mature, plant height in inches, and 1000 kernel weight in grams from Experiments 3 and 4

Variety	Height in Inches			Kernel Wt. in Gms.		
	Experiment		Mean	Experiment		Mean
	3	4		3	4	
Canus	51.0	38.8	44.9	35.6	33.8	34.7
Caesium	60.2	42.6	51.4	35.4	29.0	32.2
H-37-30	59.9	43.3	51.6	35.6	29.8	32.7
Erythrospermum .0341	53.6	39.7	46.6	39.2	36.2	37.7
H-29-35	52.6	40.0	46.3	32.0	30.0	31.0
Nabawa	52.1	40.6	46.4	50.2	45.6	47.9
Red Fife	56.1	40.1	48.1	33.4	32.8	33.1
Baart	53.4	39.9	46.6	49.6	43.6	46.6
Bena	46.1	37.5	41.8	47.4	43.6	45.5
Thatcher	46.8	34.9	40.8	31.2	29.2	30.2
Red Bobs	51.6	38.1	44.8	37.2	33.6	35.4
S-615	53.8	39.5	46.6	39.2	37.8	38.5
Ceres	52.3	38.4	45.4	37.2	34.2	35.7
Renfrew	58.0	42.9	50.4	42.2	44.8	43.5
Milturum .0321	57.9	43.0	50.4	32.4	30.6	31.5
Hard Federation	49.1	37.3	43.2	39.2	37.0	38.1
Bunyip	48.5	36.6	42.6	46.0	40.6	43.3
Kenya	57.8	43.2	50.5	40.0	33.8	36.9
Comet	43.8	34.8	39.3	41.0	37.8	39.4
Lutescens .062	57.2	43.6	50.4	35.6	33.4	34.5
Dicklow	51.6	40.7	46.2	37.2	33.0	35.1
Sikora	49.8	36.5	43.2	30.8	26.4	28.6
Garnet	48.9	36.6	42.8	31.8	27.4	29.4
Marquis	52.2	39.1	45.6	38.6	33.2	35.9
Regent 975.6	45.9	35.8	40.8	38.8	32.0	35.4
S-633	50.6	38.3	44.4	48.8	39.8	44.3
Apex	47.9	36.7	42.3	34.6	32.8	33.7
Hope	49.2	36.1	42.6	39.8	34.6	37.2
Cross Seven	45.5	36.7	41.1	40.2	37.6	38.9
Reward	47.6	35.5	41.6	37.4	30.0	33.7
Renown	46.0	34.3	40.2	38.6	29.6	34.1
General Mean	51.5	38.8	45.2	38.6	34.6	36.6

Table VI

Results of the analysis of variance of the yield, in grams per plot, for each of Experiments 3 and 4

Variance due to	D.F.	Mean squares for	
		Experiment 3	Experiment 4
Varieties	30	87140**	17563**
Incomplete blocks	30	10876	9820**
Residual	125	10384	2480

** Exceeds the 1% point

Table VII

Results of the multiple analysis of variance of the yield, in grams per plot, for Experiments 3 and 4

Variance due to	D.F.	Mean squares	F value
Experiments	1	3591136	557.20**
Varieties	30	64208	1.58
Varieties x experiments	30	40496	6.28**
Incomplete blocks	60	10348	1.60*
Residual	250	6445	
Total	371		

* Exceeds the 5% point

** Exceeds the 1% point

Table VIII

Results for the inter-experiment correlation coefficients of comparable characters in Experiments 3 and 4

Character	Correlation Coefficient
Days to head	.954**
Days to mature	.880**
Height in inches	.937**
Protein in per cent	.817**
Weight of 1000 kernels in grams	.886**

** Exceeds the 1% point

Stomatal Length

The data on this character were obtained from the five Experiments 1, 2, 4, 5 and 6 in which measurements were made on the seedling leaves. In addition, for two of these five, Experiments 4 and 5, measurements were also made on the flag leaves. The methods employed and the results obtained will be discussed separately for the two leaf stages.

Seedling Leaves

Methods - In Experiment 1, the main details of which have been already outlined in the section "Reaction to Soil Drought",

the seedling leaves were collected over a five day period immediately after watering was discontinued. The plants were then in the two to early three leaf stage. Five leaves were taken at random from each crock. These were removed, placed in water, and stored in a cold chamber (40° F.) for an hour or more before being examined. Measurements were made on the fresh leaves, ten stomata being measured per leaf. The 50 measurements per crock were tabulated and their average values used in an analysis of variance.

The data for Experiment 2 were assembled in much the same manner as for Experiment 1. In this instance a cold chamber was not available but a cool dark cupboard was found to be equally satisfactory. The lengths of ten stomata on each of five leaves, taken at random, were recorded per crock.

The leaf collections for Experiment 4 were taken in much the same manner as for the two experiments just outlined. One change was made however. Ten plants per row were staked out and, retaining individual plant identity, the seedling leaf was removed from each. The lengths of ten stomata were measured per leaf and the resulting 100 measurements were averaged for use in the analysis of variance. It will be recalled that this was a field experiment grown at Swift Current. (See the section "Agronomic Results".).

Experiment 5 was a greenhouse experiment. Equal amounts of soil of known moisture content were placed in the crocks. Ten plants were established per crock. As in Experiment 4 the ten seedling leaves were collected in such a manner as

to retain plant identity. The measuring of ten stomata per leaf gave a crock average based on 100 measurements.

Experiment 6 was a greenhouse experiment conducted in the same manner and, originally, for the same purpose as Experiments 1 and 2. Six leaves, per crock of twelve plants, were collected and ten stomata measured per leaf. Therefore replicate averages were based on 60 measurements. The cold chamber, as reported for Experiment 1, was used in this experiment.

In all of the five experiments outlined above leaf collections were made according to a plan based on statistical considerations. All of the leaves from all of the six varieties in an incomplete block were collected at one time and were measured by one operator. By this means incomplete block variance would remove possible systematic errors.

Results - The seedling leaf stomatal lengths, in microns, for all of the 31 varieties in each of the five experiments are presented in Table IX, the varieties being listed in order of decreasing mean stomatal length. The results for the individual analyses of variance are presented in Table X, and the results of a multiple analysis for the five experiments in Table XI. The ten possible inter-experiment correlation coefficients calculated from the data in Table IX are presented in Table XII.

Variety variance was highly significant in every experiment and for the average of the five experiments. All of

these experiments are uniform in that their residual variances are very small and both variety and incomplete block variances were always highly significant. In all cases the range in length is very small, varying from 9 to 11 microns in individual experiments, with the range of the means being 8 microns. At the same time the range was usually four or more times greater than the corresponding necessary difference.

The multiple analysis presented in Table XI reveals that there was a significant variety x experiment interaction. This did not materially alter the significance of variety variance because, when interaction variance replaced residual variance for testing significance, a highly significant F value of 18.08 was obtained. The necessary difference in the 'mean' column of Table IX was calculated from interaction variance. The variance due to experiments was highly significant but as the greatest deviation of the mean of any experiment from the general mean was only 1.6 microns environmental factors seemingly had little influence on the magnitude of stomatal length.

The uniformity in the size of the inter-experiment correlation coefficients presented in Table XII is striking. They are all highly significant and of sufficient magnitude to indicate good agreement between any two of the individual trials.

Table IX

Seedling leaf stomatal lengths, in microns, of the 31 varieties in Experiments 1, 2, 4, 5 and 6

Variety	Seedling stomatal length in microns					
	Experiment					Mean
	1	2	4	5	6	
Sikora	81.0	79.3	80.8	84.1	81.9	81.4
Thatcher	80.5	82.7	80.3	81.5	81.1	81.2
Hope	80.2	80.3	79.2	83.1	81.1	80.8
Regent 975.6	81.2	80.7	79.6	81.1	80.5	80.6
Red Fife	81.0	77.6	78.5	82.5	82.7	80.5
Baart	79.8	78.9	82.9	80.3	79.6	80.3
Garnet	79.2	79.8	80.1	82.2	80.4	80.3
Lutescens .062	81.6	79.9	77.0	82.4	79.4	80.1
Renown	79.4	79.6	80.5	81.5	79.0	80.0
Cross Seven	79.2	75.6	80.8	82.6	80.0	79.7
Renfrew	79.1	78.3	80.6	79.4	79.2	79.3
Comet	78.2	78.6	78.2	79.2	81.7	79.2
Reward	81.0	78.8	76.8	79.4	80.0	79.2
Marquis	78.9	77.5	79.1	82.1	77.0	78.9
Ceres	78.5	78.9	78.4	80.0	78.0	78.8
Bunyip	78.6	75.7	79.4	79.0	79.4	78.4
H-29-35	76.8	76.7	77.6	81.0	78.4	78.1
Milturum .0321	75.4	77.7	79.5	80.3	77.4	78.0
Apex	77.1	76.7	75.4	80.4	78.3	77.6
Hard Federation	75.2	78.0	77.1	80.6	76.3	77.4
H-37-30	75.2	76.0	77.3	79.3	76.2	76.8
S-615	75.8	75.2	76.3	77.8	77.9	76.6
Erythrospermum .0341	77.0	75.0	75.7	77.5	76.5	76.3
Canus	74.4	74.8	75.7	76.8	75.5	75.4
Kenya	74.3	74.4	76.4	76.5	75.1	75.4
Nabawa	74.3	72.7	74.7	77.4	76.7	75.2
S-633	75.1	72.5	73.8	75.6	76.0	74.6
Bena	73.8	71.3	74.7	78.0	74.7	74.5
Caesium	72.6	73.2	74.8	78.3	73.6	74.5
Dicklow	74.0	73.9	73.7	74.7	75.7	74.4
Red Bobs	72.9	73.4	74.5	73.2	72.5	73.3
General Mean	77.5	76.9	77.7	79.6	78.1	78.0
Necessary Difference	1.9	2.2	2.1	2.3	2.0	1.1

Table X

Results of the analyses of variance of the seedling leaf stomatal lengths, in microns, for Experiments 1, 2, 4, 5 and 6

Variance due to	D.F.	Mean squares for Experiments				
		1	2	4	5	6
Varieties	30	40.05**	40.40**	30.61**	34.74**	33.48**
Incomplete blocks	30	20.40**	16.85**	27.76**	40.66**	13.17**
Residual	125	2.16	3.08	2.77	3.45	2.47

** Exceeds the 1% point

Table XI

Results of the multiple analysis of variance of the seedling leaf stomatal lengths, in microns, for all five Experiments 1, 2, 4, 5 and 6

Variance due to	D.F.	Mean squares	F value
Experiments	4	193.66	69.41**
Varieties	30	146.80	18.08**
Varieties x experiments	120	8.12	2.91**
Incomplete blocks	150	23.77	8.52**
Residual	625	2.79	
Total	929		

** Exceeds the 1% point

Table XII

Inter-experiment correlation coefficients between the variety mean seedling leaf stomatal lengths as determined in Experiments 1, 2, 4, 5 and 6

Experiment	6	5	4	2
1	.914**	.787**	.737**	.834**
2	.770**	.742**	.754**	-
4	.714**	.742**	-	-
5	.767**	-	-	-

** Exceeds the 1% point

Flag Leaves

Methods - In Experiment 4 the flag leaves were collected from the ten plants in each row which were marked as having been included in the seedling leaf samples. The collections were made after all of the varieties had headed. This was actually later than desired because some losses occurred in the earlier varieties where hot winds had caused premature leaf maturation. This loss rarely exceeded five leaves per row. The average stomatal length per row, allowing for reduced numbers when necessary, was used in an analysis of variance. Owing to exigencies of time and transportation it was necessary to collect the leaves, preserve them, and measure the stomatal lengths at a later date. To this end the leaves were placed in a formalin - acetic acid - ethyl alcohol solution as they were collected and stored in this for three months before the measurements were taken. This procedure did not appear to affect the results obtained.

The greenhouse material, Experiment 5, was handled in the fresh condition. Leaf collections were commenced when the first varieties had headed and were made on a variety basis throughout this experiment. As in Experiment 4 plant identity was retained. Again some plant losses occurred; these were caused chiefly by wireworm activity in the crocks after the seedling leaf collections had been made. The average stomatal length per crock was used in an analysis of variance.

The flag leaves of these two experiments developed under

markedly different conditions. Experiment 4 was grown in the field at Swift Current under excellent growing conditions. Moisture was plentiful throughout the growing season and extremes of temperature were not encountered. The environment of Experiment 5 differed from that of Experiment 4 not only in that plants were grown under greenhouse conditions but also by the fact that once the plants were established soil moisture was kept at as low a level as possible by very sparing application at infrequent intervals. The usual evidences of drought were noted for the plants of all varieties, e.g., a very heavy coating of wax or 'bloom' on the leaves and stems, a marked reduction in plant height, small leaves, and semi-sterility of the heads when they developed.

Results - Table XIII presents the findings on the variety flag leaf stomatal lengths as affected by the two conditions; the differences in length between unfavourable and favourable conditions determined the order of listing the varieties. The results of the individual and of the multiple analyses of variance are presented in Table XIV and XV respectively.

Variety variance was significantly greater than residual variance for each of the analyses included in Tables XIV and XV. The mean variety variance (Table XV) was insignificant when tested against the significant interaction variance, an F value of only .67 being obtained.

The data in Table XIII show some marked differences between these experiments. For Experiment 4 the magnitude of

the range in length and of the necessary difference, 11 and 1.8 microns respectively, were in line with those to be expected from the results obtained for measurements on the seedling leaves. These expectations were not met by the results of Experiment 5, here the range and the necessary difference were both much larger, being 23 and 5.7 microns respectively. The difference in length between experiments was highly significant with the general mean length produced under arid conditions being 5.6 microns greater than under humid conditions.

This latter result is distinctly at variance with the results of others. All other workers have found that lengths of stomata were less when the plants were subjected to drought. A partial explanation for the present results may be found in a consideration of the effect of light since one experiment was grown in the greenhouse and the other in the field.

Table XIII

Flag leaf stomatal lengths, in microns, of the 31 varieties in Experiments 4 and 5

Variety	Flag leaf stomatal length in microns			
	Experiment		Mean	Diff. 5 - 4
	4	5		
Cross Seven	49.4	70.0	59.7	20.6
Dicklow	53.6	67.2	60.4	13.6
Marquis	55.9	68.9	62.4	13.0
Red Fife	52.2	64.6	58.4	12.4
Ceres	55.8	67.8	61.8	12.0
Bena	53.0	62.9	58.0	9.9
H-37-30	53.6	63.3	58.4	9.7
Renfrew	56.5	65.9	61.2	9.4
Baart	57.0	66.1	61.6	9.1
Canus	54.8	63.9	59.4	9.1
Lutescens .062	55.5	64.4	60.0	8.9
Comet	55.6	64.4	60.0	8.8
Hope	55.4	64.0	59.7	8.6
Caesium	52.8	61.2	57.0	8.4
Hard Federation	54.2	62.5	58.4	8.3
Bunyip	56.8	64.8	60.8	8.0
Erythrospermum .0341	55.2	62.9	59.0	7.7
Milturum .0321	52.8	59.8	56.3	7.0
Kenya	54.1	60.0	57.0	5.9
S-633	54.0	59.9	57.0	5.9
Red Bobs	49.1	53.8	51.4	4.7
S-615	57.2	61.6	59.4	4.4
Nabawa	55.2	59.5	57.4	4.3
H-29-35	54.2	57.9	56.0	3.7
Apex	57.3	55.9	56.6	-1.4
Reward	59.8	55.6	57.7	-4.2
Thatcher	58.5	53.9	56.2	-4.6
Garnet	55.5	50.6	53.0	-4.9
Regent 975.6	57.5	50.4	54.0	-7.1
Renown	57.5	48.2	52.8	-9.3
Sikora	56.0	46.7	51.4	-9.3
General Mean	55.0	60.6	57.8	5.6
Necessary Difference	1.8	5.7	6.8	-

Table XIV

Results of the analyses of variance of the flag leaf stomatal lengths, in microns, for Experiments 4 and 5

Variance due to	D.F.	Mean squares for	
		Experiment 4	Experiment 5
Varieties	30	28.81$^{\boxtimes\boxtimes}$	192.13$^{\boxtimes\boxtimes}$
Incomplete blocks	30	10.66$^{\boxtimes\boxtimes}$	68.11$^{\boxtimes\boxtimes}$
Residual	125	1.93	21.29

$^{\boxtimes\boxtimes}$ Exceeds the 1% point

Table XV

Results of the multiple analysis of variance of the flag leaf stomatal lengths, in microns, for Experiments 4 and 5

Variance due to	D.F.	Mean squares	F value
Experiments	1	2890.78	248.99$^{\boxtimes\boxtimes}$
Varieties	30	88.92	.67
Varieties x experiments	30	132.02	11.37$^{\boxtimes\boxtimes}$
Incomplete blocks	60	39.38	3.39$^{\boxtimes\boxtimes}$
Residual	250	11.61	
Total	371		

$^{\boxtimes\boxtimes}$ Exceeds the 1% point

Stomatal Length Reduction in Per Cent

Methods - The data for average stomatal lengths from the seedling and flag leaves of Experiments 4 and 5 were used to compute the values considered in this section. In the review of literature it was revealed that several workers (20, 45, 58, 61) reported a gradient in stomatal length within the plant, the greatest length occurring on the lowest leaf. With this in mind the seedling leaf stomatal length was considered as the maximum length and the reduction to length of stomata on the flag leaves calculated as a percentage of the maximum length. The replicate averages were substituted in the formula:

$$\frac{\text{Seedling length} - \text{Flag length}}{\text{Seedling length}} \times 100 = \text{per cent length reduction}$$

These percentage values were treated by means of an analysis of variance. No transformations of the percentage data were made since these cannot be classified as discrete data (5).

Results - The variety mean values, for the percentage stomatal length reductions between the seedling and flag leaves in Experiments 4 and 5, are presented in Table XVI. The varieties are listed by their difference, in percentage reduction, between the two experiments. Analyses of variance of the individual experiments and of a multiple for the two experiments are presented in Tables XVII and XVIII, respectively.

The individual analyses in Table XVII show variety variance to be highly significant. Variety variance also

significantly exceeds residual variance in Table XVIII. However when variety variance was tested against the significant interaction variance, Table XVIII, a non-significant F value of .87 was obtained. The interaction may be partially evaluated from the 'difference' column in Table XVI.

The two experiments show marked differences in the amount of length reduction exhibited by individual varieties under the two environmental conditions. In Experiment 4 the extremes form a range of 16 per cent, from a low of 22 per cent to a high of 38 per cent length reduction. In Experiment 5 the range is 35 per cent, from a low of 10 per cent to a maximum of 45 per cent. The mean percentage reduction was significantly less when the flag leaves were developed under the dry conditions of Experiment 5.

Table XVI

Stomatal length reduction, as a percentage of the seedling leaf stomatal length, between the seedling and flag leaves of the 31 wheat varieties in Experiments 4 and 5

Variety	Length reduction in per cent			
	Experiment 4	Experiment 5	Mean	Diff. 4 - 5
Cross Seven	38.5	15.2	26.9	23.3
Dicklow	27.3	9.9	18.6	17.4
Marquis	30.3	16.1	22.6	14.2
Baart	31.4	17.3	24.3	14.1
Ceres	28.7	15.2	21.9	13.5
Renfrew	29.8	16.8	23.3	13.0
Red Fife	33.6	21.6	27.6	12.0
Canus	27.6	16.4	22.0	11.2
H-37-30	30.6	20.0	25.3	10.6
Comet	28.9	18.4	23.7	10.5
Bunyip	28.4	18.0	23.2	10.4
Bena	29.0	19.2	24.1	9.8
Milturum .0321	33.6	25.4	29.5	8.2
Erythrospermum .0341	26.8	18.8	22.8	8.0
Caesium	29.5	21.8	25.7	7.7
Hard Federation	29.8	22.1	26.0	7.7
Kenya	29.1	21.5	25.3	7.6
Red Bobs	34.0	26.5	30.3	7.5
Hope	30.0	22.8	26.4	7.2
Lutescens .062	27.9	21.6	24.8	6.3
S-633	26.6	20.5	23.5	6.1
S-615	24.8	20.7	22.8	4.1
Nabawa	26.1	23.1	24.6	3.0
H-29-35	29.9	28.5	29.2	1.4
Apex	24.1	30.3	27.2	-6.2
Thatcher	27.0	33.7	30.4	-6.7
Garnet	30.8	38.1	34.4	-7.3
Reward	22.2	29.8	26.0	-7.6
Regent 975.6	27.7	37.9	32.8	-10.2
Renown	28.5	40.8	34.6	-12.3
Sikora	30.7	44.6	37.6	-13.9
General Mean	29.1	23.6	26.4	5.5
Necessary Difference	3.2	7.8	8.7	-

Table XVII

Results of the analysis of variance of the stomatal length reductions, in per cent, for each of Experiments 4 and 5

Variance due to	D.F.	Mean squares for	
		Experiment 4	Experiment 5
Varieties	30	507.68**	352.74**
Incomplete blocks	30	248.81**	164.38**
Residual	125	6.66	39.31

** Exceeds the 1% point

Table XVIII

Results of the multiple analysis of variance of the stomatal length reductions, in per cent, for Experiments 4 and 5

Variance due to	D.F.	Mean squares	F value
Experiments	1	2779.80	120.97**
Varieties	30	187.83	.87
Varieties x experiments	30	215.68	9.38**
Incomplete blocks	60	94.63	4.12**
Residual	250	22.98	
Total	371		

** Exceeds the 1% point

Interrelationships

The data from the foregoing sections form the basis for the results presented in this section. To a part of these data covariance analyses were applied, and to the rest the methods of simple, partial, and multiple correlation.

Covariance Analyses

Certain of the experiments reported in this thesis were set up to study specific relationships. This fact suggests that more information might be obtained by analyses of covariance than is usually secured by the method of simple correlation. The data from Experiments 1 and 2 for seedling leaf stomatal length and soil drought survival and from Experiments 4 and 5 for seedling leaf and flag leaf stomatal lengths were therefore subjected to analyses of covariance. The results obtained are presented in the two sections immediately following.

Seedling Leaf Stomatal Length and Soil Drought Survival - For each of Experiments 1 and 2 the mean replicate (crock) values for seedling leaf stomatal length in microns and soil drought survival in per cent, were utilized in a covariance analysis. The results of these analyses are presented in Tables XIX and XX. Table XXI presents a test of significance of the regression coefficient for percentage survival on seedling leaf stomatal length calculated from the mean values of the two experiments. Scatter diagrams plotted from the

variety means of the two characters in Experiments 1 and 2 and their two-experiment means are presented in Figures 2, 3, and 4, respectively.

The results of the analysis are similar in both cases. Regression was significantly different within and between varieties, therefore to adjust the survival percentages for their regression on stomatal length only the regression within varieties should be used. The regression lines shown in Figures 2 and 3 were drawn using the variety regression coefficients. The variety differences in survival are only partially explained by differences in seedling leaf stomatal length.

The significance of the correlation coefficients are indicated in the respective tables. In Experiment 2 and for the means of the two experiments there was a significant negative correlation between survival and stomatal length.

Table XIX

Analysis of covariance between percentage survival (S) and stomatal length (L) in Experiment 1

Variance due to	D.F.	S^2	SL	L^2	D.F.	b_{sl}	$b_{sl}SL$	Corr. S^2	r_{sl}
Total	185	18884.31	-348.77	2084.19					
Incomplete blocks	30	4422.51	487.10	612.03					
Varieties	30	6992.57	-938.23	1201.49	29	-.781	732.76	6259.81	-.327
Residual	125	7469.23	102.36	270.67	124	.378	38.69	7430.54	
Varieties + Residual	155	14461.80	-835.87	1472.16	154	-.568	474.77	13987.03	

Variance due to	D.F.	Corr. S^2	Variance	F value
Varieties + Residual	154	13987.03		
Residual	124	7430.54	59.92	
Varieties (Difference)	30	6556.49	218.55	3.65**
Varieties	29	6259.81	215.86	3.60**
$b_v - b_r$	1	296.68	296.68	4.95*

* Exceeds the 5% point

** Exceeds the 1% point

Table XX

Analysis of covariance between percentage survival (S) and stomatal length (L) in Experiment 2

Variance due to	D.F.	S^2	SL	L^2	D.F.	b_{sl}	$b_{sl}SL$	Corr. S^2	r_{sl}
Total	185	40637.52	-2953.49	2102.88					
Incomplete blocks	30	13189.09	- 642.57	505.62					
Varieties	30	19881.17	-2243.54	1212.01	29	-1.851	4152.79	15728.38	$-.457^{xx}$
Residual	125	7567.26	- 67.38	385.25	124	- .175	11.79	7555.47	
Varieties + Residual	155	27448.43	-2310.92	1597.26	154	-1.447	3543.90	24104.53	

Variance due to	D.F.	Corr. S^2	Variance	F Value
Varieties + Residual	154	24104.53		
Residual	124	7555.47	60.93	
Varieties (Difference)	30	16549.06	551.64	9.05^{xx}
Varieties	29	15728.38	542.36	8.90^{xx}
$b_v - b_r$	1	820.68	820.68	13.47^{xx}

^{xx} Exceeds the 1% point

Table XXI

Test of significance of the regression coefficient for mean percentage survival on mean stomatal length from Experiments 1 and 2

Variance due to	D.F.	Mean square	F value
Regression	1	4461.45	7.72 xx
Deviations from regression	29	577.61	
Total	30		

Coefficient of regression = -1.42

Coefficient of correlation = -.459 xx

xx Exceeds the 1% point

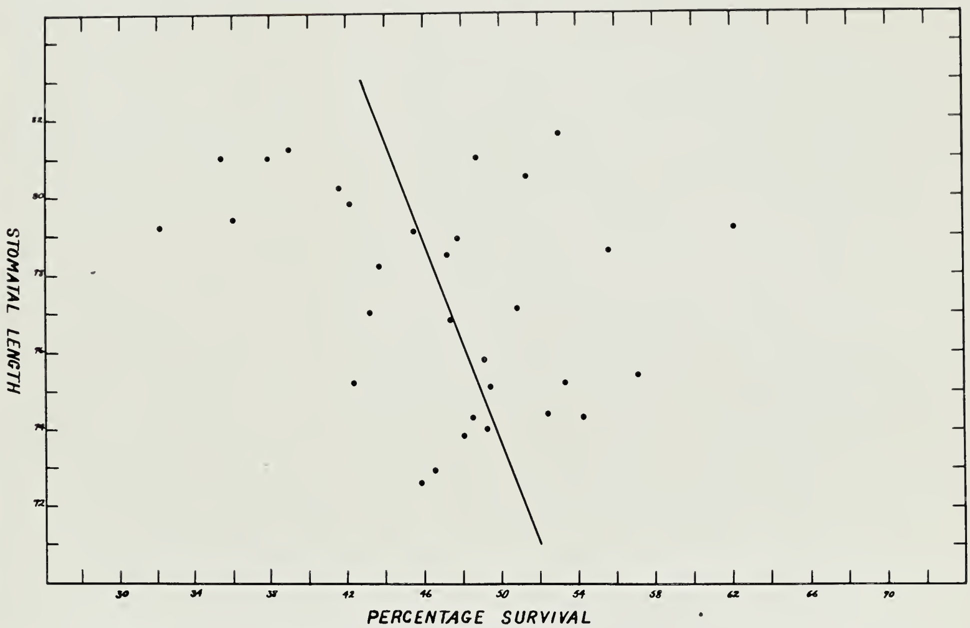

Figure 2 - The relation between percentage soil drought survival and seedling leaf stomatal length in microns, data from Experiment 1.

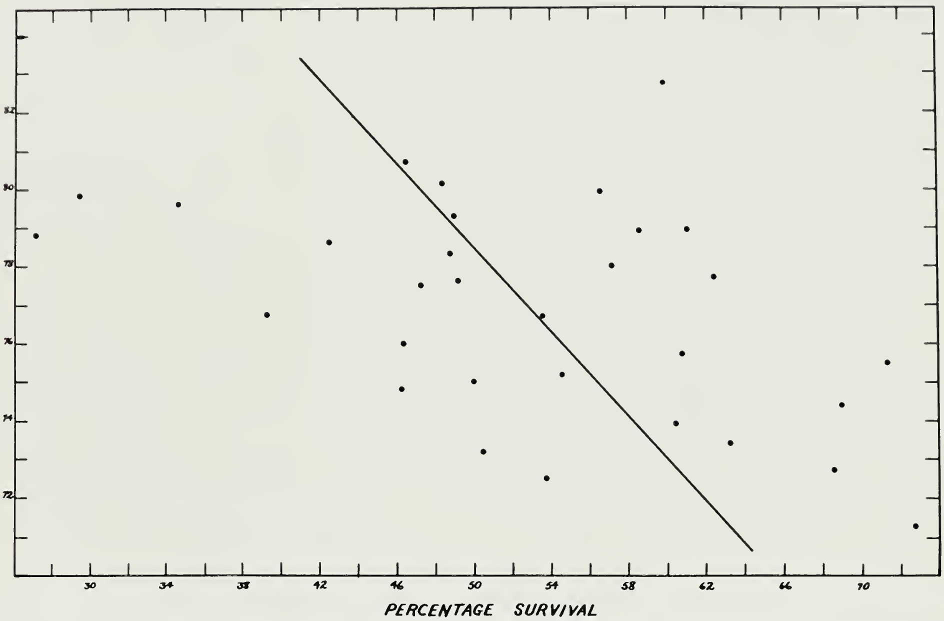

Figure 3 - The relation between percentage soil drought survival and seedling leaf stomatal length in microns, data from Experiment 2.

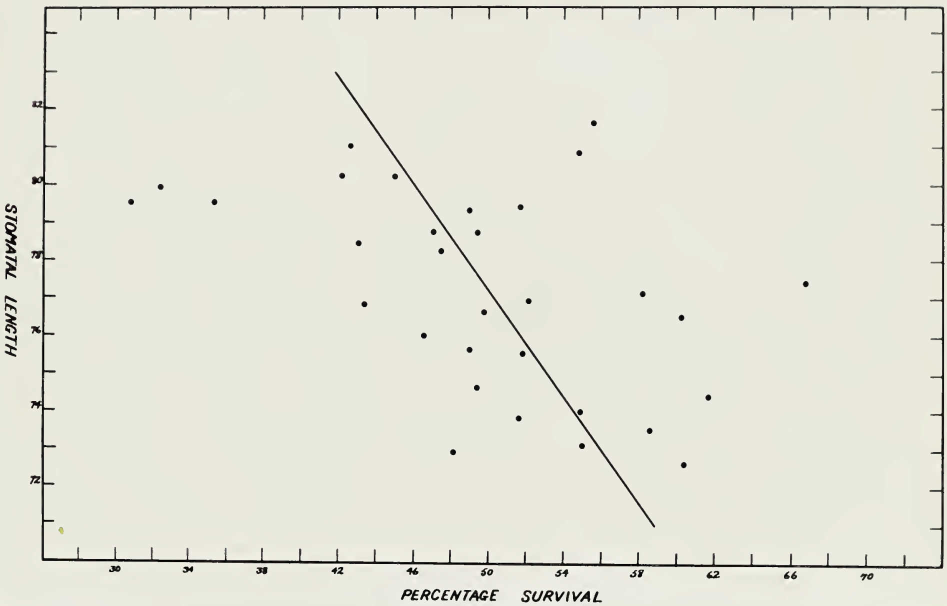

Figure 4 - The relation between percentage soil drought survival and seedling leaf stomatal length in microns, mean of data from Experiments 1 and 2.

<u>Seedling and Flag Leaf Stomatal Lengths</u> - Covariance analyses were applied to the data of Experiments 4 and 5 to examine the relation between the seedling and flag leaf stomatal lengths. The results of these analyses are presented in Tables XXII and XXIII. Figures 5 and 6 are scatter diagrams prepared from the variety means for the two characters in Experiments 4 and 5 respectively.

The results presented demonstrate that there is no significant reduction in the variance due to flag leaf stomatal length when the variance due to its regression on seedling leaf stomatal length is removed. In Experiment 4 the regressions within and between varieties are significantly different while in Experiment 5 these differences are insignificant.

The scatter diagrams provide little additional information although Figure 6 suggests a non-linear relation between the two stomatal lengths.

Table XXII

Analysis of covariance between seedling (S) and flag (F) leaf stomatal length in Experiment 4

Variance due to	D.F.	F^2	FS	S^2	D.F.	b_{fs}	$b_{fs}FS$	Corr. F^2	r_{fs}
Total	185	1425.49	382.06	2097.94					
Incomplete blocks	30	319.73	189.70	832.89					
Varieties	30	864.43	264.65	918.33	29	.288	76.22	788.21	.297
Residual	125	241.33	-72.29	346.72	124	-.208	15.04	226.29	
Varieties + Residual	155	1105.76	192.36	1265.05	154	.152	29.24	1076.52	

Variance due to	D.F.	Corr. F^2	Variance	F Value
Varieties + Residual	154	1076.52		
Residual	124	226.29	1.82	
Varieties (Difference)	30	850.23	28.34	15.57**
Varieties	29	788.21	27.18	14.93**
$b_v - b_r$	1	62.02	62.02	34.08**

** Exceeds the 1% point

Table XXIII

Analysis of covariance between seedling (S) and flag (F) leaf stomatal length in Experiment 5

Variance due to	D.F.	F^2	FS	S^2	D.F.	b_{fs}	$b_{fs}FS$	Corr. F^2	r_{fs}
Total	185	10467.91	-681.46	2692.88					
Incomplete blocks	30	2043.17	-241.41	1219.71					
Varieties	30	5763.98	-329.90	1042.32	29	-.316	104.25	5659.73	-.147
Residual	125	2660.76	-110.15	430.85	124	-.256	28.20	2632.56	
Varieties + Residual	155	8424.74	-440.05	1473.17	154	-.299	131.57	8293.17	

Variance due to	D.F.	Corr. F^2	Variance	F Value
Varieties + Residual	154	8293.17		
Residual	124	2632.56	21.23	
Varieties (Difference)	30	5680.61	188.69	8.89xx
Varieties	29	5659.73	195.16	9.19xx
$b_v - b_r$	1	.88	.88	

xx Exceeds the 1% point

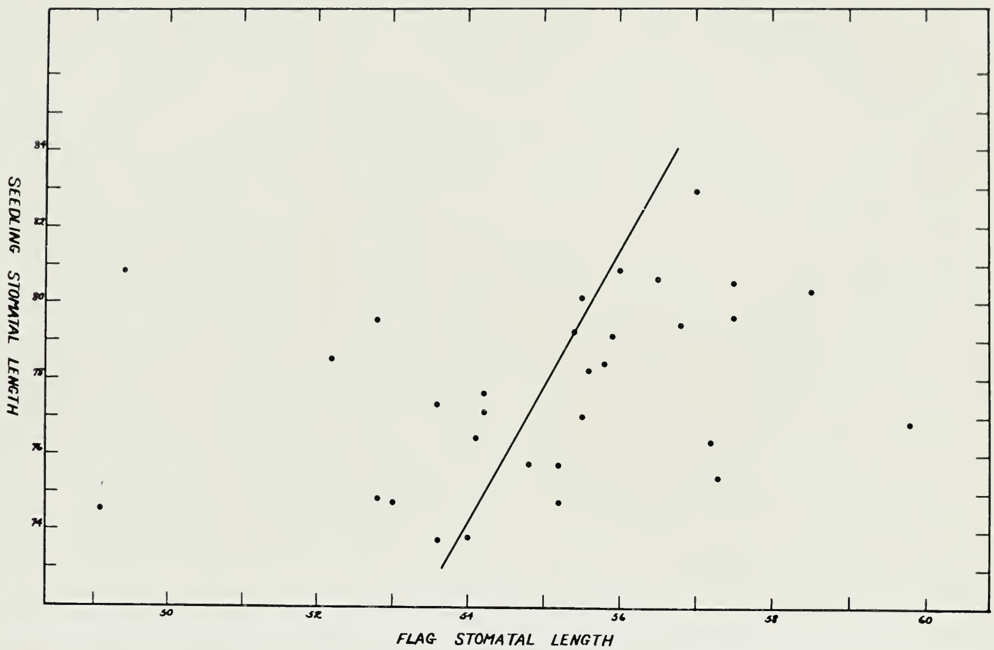

Figure 5 - The relation between seedling leaf and flag leaf stomatal lengths, data from Experiment 4.

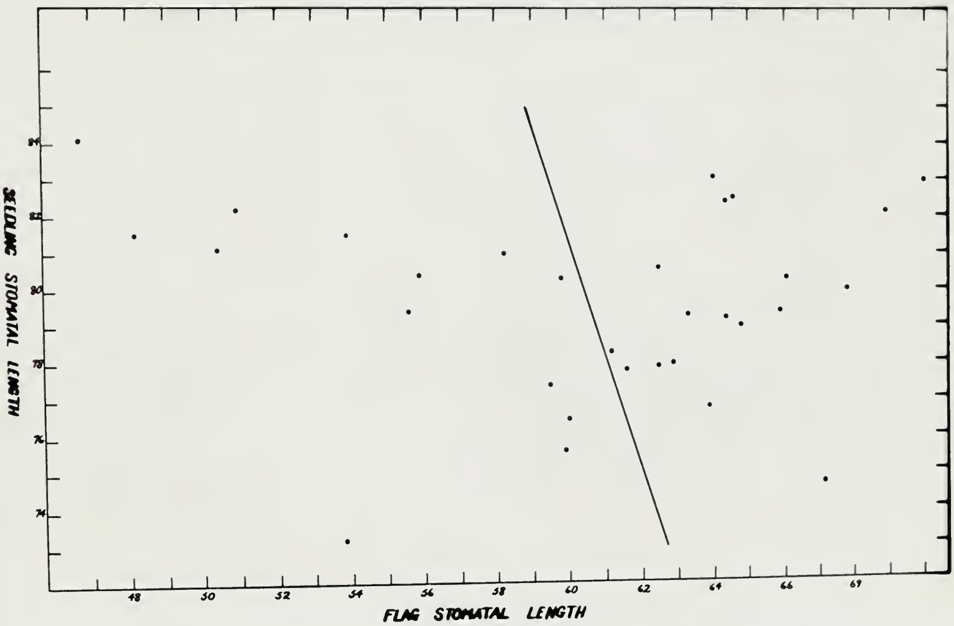

Figure 6 - The relation between seedling leaf and flag leaf stomatal lengths, data from Experiment 5.

<u>Test of Curvilinearity</u> - As noted in the preceding section the data plotted in Figure 6 suggest that any existent relationship is not necessarily linear.

Snedecor (48) outlines a method for testing curvilinearity which is readily adapted to any replicated experiment. A second independent variable is derived by utilizing some arithmetic conversion of the original independent variable. In these experiments seedling leaf stomatal length is the independent variable and the second independent was derived by taking the square root of the individual values. The seedling leaf stomatal length, its square root, and the flag leaf stomatal length were analyzed by the method of partial regressions as outlined by Crampton and Hopkins (9). The significance of the reduction in the amount of residual variance due to the quadratic effect is tested by comparing the ratio of the quadratic residual variance to that of the difference between the linear and quadratic residual variances (48, p. 322).

This test of curvilinearity was applied to the stomatal data of Experiments 4 and 5 and the results are presented in Table XXIV.

There was a significant deviation from linearity in the data of Experiment 5 as evidenced by the highly significant F value. Experiment 4 shows no departure from linearity. The proof of non-linearity does not alter any statements made in preceding sections but the original covariance analysis as

presented in Table XXIII is invalidated by this demonstration of curvilinear regression.

Table XXIV

Results for a test of significance of departure from residual linear regression in the seedling and flag leaf stomatal length data of Experiments 4 and 5

Variation due to	D.F.	Corrected Sum of Squares	Mean Square	F Value
EXPERIMENT IV				
Reduction due to quadratic regression	1	.44	.44	.24
Deviations from quadratic regression	123	225.85	1.84	
Deviations from linear regression	124	226.29		
EXPERIMENT V				
Reduction due to quadratic regression	1	176.19	176.19	8.82 xx
Deviations from quadratic regression	123	2456.36	19.97	
Deviations from linear regression	124	2632.56		

xx Exceeds the 1% point

Character Correlations with Flag Leaf Stomatal Length

Flag leaf stomatal length was subject to a distinct interaction effect within Experiments 4 and 5. In order to utilize these data for correlation studies it was necessary to work with the data of the individual experiments. The correlations presented in Table XXV summarize the results obtained. Apart from those characters covered by the footnote to the table, the data used were the same as in the following section.

The correlation coefficients presented in Table XXVI were "within variety" correlations calculated from the data of Experiment 5. Individual plant identities were retained throughout Experiments 4 and 5 insofar as seedling and flag leaf stomatal lengths were concerned. By using the individual plant as the basis of pairing and ignoring the factor of replicates, a possible of 60 pairs per variety was available for calculating a correlation coefficient. The loss of flag leaf data in Experiment 4 reduced the number of pairs available for certain varieties to a lower level than desirable; therefore none of the data from this test were used.

Some of the correlations established were rather surprising, the absence of others still more so.

In Table XXV the inverse relation between length and the percentage length reduction of the stomata demonstrates that, while in themselves the percentage reductions are of interest, an evaluation of the differences between the two lengths will provide essentially the same information because the length

reduction is largely dependent upon flag leaf stomatal length. The correlations between seedling leaf stomatal length and the percentage length reduction were positive and significant to the 5 per cent point, being .412 and .424 for Experiments 4 and 5 respectively.

When plants developed under the normal conditions of Experiment 4 the flag leaf stomatal lengths were negatively correlated with time of maturity and with soil drought survival. In contrast, when developed under the arid conditions of Experiment 5, they were positively correlated with these same characters and with 1000 kernel weight. None of the other correlations were significant although the tendency towards opposite sign continues.

There is a distinct and rather surprising lack of significance when seedling and flag leaf stomatal lengths are correlated. In Table XXV environment produced a change in sign but no significant relation when the variety means were correlated. Three statistically significant correlation coefficients were obtained when the "within variety" correlations were calculated for Experiment 5 (Table XXVI). Other than that there is no evidence of a consistent relationship between the stomatal lengths of the two leaf levels, no conclusion can be drawn.

Table XXV

Correlation coefficients showing the relationship of flag leaf stomatal length to various other plant characters

Character correlated	Flag leaf stomatal length	
	Experiment 4	Experiment 5
Percentage length reduction[1]	-.737^{xx}	-.954^{xx}
Days to head	-.624^{xx}	.595^{xx}
Days to mature	-.558^{xx}	.754^{xx}
Mean percentage survival	-.497^{xx}	.501^{xx}
1000 kernel weight	-.014	.456^{xx}
Plant height	-.267	.359
Per cent protein	.274	-.193
Seedling leaf stomatal length[1]	.297	-.147

^{xx} Exceeds the 1% point

(1) Determined within each experiment and so correlated, all other values were means of two experiments.

Table XXVI

The relation between seedling and flag leaf stomatal lengths for the varieties in Experiment 5 as shown by "within variety" correlation coefficients

Variety	N	r
Dicklow	54	.227
Erythrospermum .0341	59	.206
H-29-35	60	.206
Nabawa	59	.172
Reward	56	.126
Baart	55	.114
Renfrew	53	.062
Garnet	60	.046
H-37-30	57	.044
Red Bobs	60	.037
Canus	53	.013
Regent 975.6	55	-.004
Renown	45	-.008
Marquis	58	-.010
Bunyip	53	-.016
S-615	50	-.030
Bena	60	-.034
Thatcher	60	-.046
Lutescens .062	55	-.050
Apex	60	-.073
Kenya	59	-.110
Comet	57	-.121
Milturum .0321	55	-.123
Ceres	57	-.150
Hope	60	-.158
Sikora	58	-.168
S-633	53	-.174
Cross Seven	59	-.244
Red Fife	59	-.270[x]
Hard Federation	57	-.351[xx]
Caesium	57	-.455[xx]

[x] Exceeds the 5% point

[xx] Exceeds the 1% point

General Plant Character Correlations

The correlation coefficients presented in Table XXVII were calculated from the variety means of Tables I, V and IX. The characters correlated are soil drought survival, seedling leaf stomatal length, plant height, days to head and to mature, protein content and 1000 kernel weight.

Soil drought survival was significantly correlated with several characters; positively with days to head, days to mature, and 1000 kernel weight, negatively with protein content and seedling leaf stomatal length. Seedling leaf stomatal length was positively correlated with protein content and negatively with days to mature. Days to head and days to mature were both positively correlated with plant height and highly correlated with each other. Protein content was negatively correlated with 1000 kernel weight.

Table XXVII

Correlation coefficients showing the relationships between characters other than yield

Characters correlated	Soil drought survival	Seedling stomatal length	Plant height	1000 kernel weight	Protein content	Days to mature
Days to head	.653^{xx}	-.255	.489^{xx}	.145	-.292	.897^{xx}
Days to mature	.644^{xx}	-.404^{x}	.471^{xx}	.323	-.216	-
Per cent protein	-.430^{x}	.422^{x}	.062	-.430^{x}	-	-
1000 kernel weight	.397^{x}	-.290	-.044	-	-	-
Plant height	.274	-.316	-	-	-	-
Seedling leaf stomatal length	-.394^{x}	-	-	-	-	-

^{x} Exceeds the 5% point

^{xx} Exceeds the 1% point

Yield and Related Plant Characters

Total correlations between yield and the agronomic characters, i.e., height, days to head, days to mature, protein content, and 1000 kernel weight, are presented in the first portion of Table XXVIII. In the second part of the same table the yields are correlated with (a) the mean drought survival percentages of Table I, (b) the mean seedling leaf stomatal lengths of Table IX, and (c) the flag leaf stomatal lengths of the individual experiments as presented in Table XIII. The yield data from the individual experiments were used for the purpose of correlation because of the high interaction and consequent non-significance of the mean yields (Table VII). The same condition occurred in the flag leaf stomatal length data (Table XV).

The yields in Experiment 3 were positively correlated with only two other characters - plant height and the flag leaf stomatal lengths of Experiment 3. No significant negative correlations were established.

The yield data of Experiment 4 gave significant correlations in the majority of cases. Yield was positively correlated with height, days to head, days to mature, drought survival, and with the flag leaf stomatal length of Experiment 5. Negative correlations were recorded when either protein content or seedling leaf stomatal lengths were correlated with yield. The negative correlation between yield and the flag leaf stomatal lengths of Experiment 4 approaches significance.

Table XXVIII

Correlation coefficients showing the relationship of yield to various other plant characters

Character correlated (1)	Yield in bushels	
	Experiment 3	Experiment 4
Height in inches	.494^{xx}	.551^{xx}
Days to head	-.125	.584^{xx}
Days to mature	-.021	.642^{xx}
Protein content in per cent	-.081	-.368^{x}
1000 kernel weight in grams	-.143	.337
Mean soil drought survival	.098	.494^{xx}
Mean seedling leaf stomatal length	-.275	-.521^{xx}
Flag leaf stomatal length - Expt.4	-.195	-.342
Flag leaf stomatal length - Expt.5	.410^{x}	.441^{x}

^{x} Exceeds the 5% point

^{xx} Exceeds the 1% point

(1) The first five characters were determined within each experiment and correlated with their corresponding yields.

Yield the Dependent in Partial Correlations

The simple, first, and fourth order partial correlation coefficients and a multiple correlation coefficient for yield correlated with survival, days to head, protein content, seedling leaf stomatal length, and height are presented in Table XXIX. The second and third order partials were not calculated as it was felt that they would provide little additional information.

These characters were selected because of their significant correlations with yield in Table XXVIII. Only the yield data of Experiment 4 were used. The simple correlations between yield and the mean values for height, protein content, and days to head were calculated and this explains the discrepancies between the values reported in Tables XXVIII and XXIX. This was done in order to utilize the values for the other plant character relationships (presented in Table XXVII).

Yield is positively correlated with survival. The association is decreased when considered independent of protein content, stomatal length, or height and becomes negligible when considered independent of days to head. There is no association between yield and survival when considered independent of the four remaining variables.

Yield and days to head are positively correlated. The relation remains the same when it is considered independent of protein content or stomatal length but the association is

decreased when considered independent of survival or height. Considered independent of all four variables the correlation between yield and days to head was non-significant.

The association between yield and protein content is improved when considered independent of height but non-significant when any one of the three remaining characters or all four were considered.

The negative relation between yield and seedling leaf stomatal length is unchanged or only slightly decreased when considered independent of any one of the other four variables but is not significant when all four are treated collectively.

Height and yield are positively correlated. This relation is improved when considered independent of protein content but is decreased to non-significant levels when considered independent of any of the other three or of all four characters.

The multiple correlation coefficient was calculated for yield dependent on these five characters, survival, days to head, protein content, stomatal length, and height, and was found to be highly significant.

This section reveals that the effects of each of these characters, while associated with yield to some degree, must also be somewhat independent. This is shown by the fact that R is considerably higher than any component. Despite this the total portion of yield variability which can be explained by the variability in these yield factors is only about 52 per cent ($.723^2 \times 100$). The value of these characters in making

selections is therefore not as great as one would wish.

Table XXIX

Simple, partial, and multiple correlations having yield as the dependent variable

Yield (1) correlated with									
Survival (2)		Days to head (3)		Protein (4)		Stomatal length (5)		Height (6)	
r	Coef.	r	Coef.	r	Coef.	r	Coef.	r	Coef.
12	.494^{xx}	13	.572^{xx}	14	-.424^{x}	15	-.621^{xx}	16	.428^{x}
12.3	.193	13.2	.380^{x}	14.2	-.270	15.2	-.408^{x}	16.2	.350
12.4	.381^{x}	13.4	.466^{xx}	14.3	-.353	15.3	-.473^{xx}	16.3	.207
12.5	.367^{x}	13.5	.553^{xx}	14.5	-.264	15.4	-.416^{x}	16.4	.503^{xx}
12.6	.433^{x}	13.6	.460^{x}	14.6	-.500^{xx}	15.6	-.449^{x}	16.5	.326
12.3456	.008	13.2456	.324	14.2356	-.260	15.2346	-.309	16.2345	.206

$R_{1.23456} = .723^{xx}$

^{x} Exceeds the 5% point

^{xx} Exceeds the 1% point

DISCUSSION

The results obtained from a study of eight characters in 31 varieties and lines of spring wheat are presented in this thesis. While isolated studies have been reported in which the relationships of certain of these characters were investigated, there is no record of any previous study in which all of these characters have been investigated with one lot of material.

The data presented are fairly representative of what may be expected, with the exception of yield. The yield data are admittedly inadequate and the further complication of abnormally high yields with a high degree of interaction makes their usefulness in correlations rather questionable. The yield data of Experiment 4 are fairly typical of the yielding abilities of individual varieties and as a consequence their correlations with other characters may be of some value.

The strengths of the various relationships were, in all cases, evaluated by means of simple correlation coefficients. Many of the coefficients were significant statistically but their practical significances cannot be measured by the same criterion. To be of practical value they would need to be very high, from .85 up. Such correlations are rare in biological material unless the characters are linked genetically or physiologically. Only in one case in these studies did

such a correlation occur; that between days to head and days to mature was .90, here the relation is physiological and rather close. The degree of dependence to be placed on a correlation is further restricted by considering the number of pairs entering into its calculation. In this instance the number (31) is at the lower limit of dependability. That more varieties or lines were not used is unfortunate, but to have done so would have meant unduly prolonging the entire study and at the same time postponing even a preliminary evaluation of the several methods.

As a basis for the selection of high yielding types seedling leaf stomatal length shows some promise. Since it is negatively correlated with yield the selection of plants or lines with shorter stomata would remove a proportion of the lower yielding lines in early generations. One feature of this character which would be of considerable importance is that it cannot be measurably influenced by environment. All the available evidence supports this conclusion; studies by Sande-Bakhuyzen (46), Birdsall (2), and those included in this report are all in agreement. The reason for this is fairly evident and has already been pointed out (46), - the seedling leaf characters are almost exclusively predetermined by embryonic development.

The use of stomatal length as a means of selection has certain disadvantages. To begin with, the character is microscopic in size and for speedy determination requires a specialized ocular attachment for the ordinary microscope. Of such

attachments relatively few are available in Canada. The variation in length within and between plants would require that at least 25-50 stomata per plant be measured if individual plants were being used, while with lines it would be necessary to measure ten stomata on each of ten or more leaves. The amount of work involved suggests that it would be of limited application. A further limitation is imposed by the extremely small range in length displayed by these otherwise widely different varieties; this would mean that only plants approaching either limit could be classified with any degree of certainty. These limits would vary with the material being examined.

In contrast to that of the seedling leaf the character of stomatal length on the flag leaves holds little promise of serving any very useful purpose. Dependent on the conditions under which the leaves develop negative or positive correlations with yield and with maturity can be readily demonstrated. It is obvious that a character so markedly influenced by environmental conditions would have little or no value as a medium for selecting high yielding types.

The simplicity of the soil drought survival method is emphasized. The equipment necessary is available in any greenhouse. A large number of plants may be handled without much work, and the positive relation between survival and yield suggests that the yield level of any population might be raised using this method of selection. Offsetting these obvious advantages of the method is the rather strong positive relation between survival and maturity. If the net result were to

select the later maturing plants, as indicated by the simple and partial correlations, then the method fails in its intended purpose of selecting for yielding ability under dry conditions and becomes merely a device for eliminating the earlier maturing lines. That this is the effect is suggested by the partial correlation coefficient $r_{12.3}$ (Table XXIX).

In wheat breeding it is necessary to determine protein content in order to produce varieties acceptable to the baking trade. In evaluating such data the negative relationship with yield should receive consideration. Since there can be no compromise with satisfactory quality low protein lines must be discarded regardless of yielding ability. On the other hand lines having very high protein might also be discarded as such lines are unlikely to have suitable yielding ability. As it is impractical to determine the protein content of material in early generations this method is most likely to prove useful as a selecting agent when used in conjunction with some other method which can be applied to the earlier generations, e.g., stomatal length or soil drought survival.

Maturity and yield appear to be positively associated in this and other studies. This factor is not always considered when hybrid populations are being worked over. While late maturing lines appear to be the highest yielding they have agronomic disadvantages that usually outweigh the extra yield. Such disadvantages are greater danger from frost, late summer drought, excessive rain, insect pests, and certain plant

diseases. It is therefore necessary to find the high yielding early types that do exist. Such lines are likely to be difficult to locate and any assistance that can be rendered by the use of such characters as stomatal length should prove valuable.

The interest in maturity is not limited to its possible usefulness for selection purposes. As a result of the positive correlation between maturity and survival, interest is aroused in certain physiological aspects of the problem. Waldron (52) found that the earlier spring wheats were more susceptible to frost, and, when judged by yield under semi-arid conditions, more susceptible to drought. The influence of earliness was observed by Platt (41) in studies on the artificial frost reaction of wheat, oat, and barley seedlings - here again the early maturing varieties being the more susceptible. On the basis of these and other results the prevalent opinion is that the present program of wheat improvement has resulted in an increased susceptibility to frost, and, if the analogy is borne out, to drought. The relation between these physiological characters for resistance has never been investigated although the same inference appears repeatedly in the literature, that they are positively and closely correlated. With the amount of theoretical knowledge now available in respect to frost resistance and the nature of frost injury the knowledge on drought resistance might be greatly augmented if a detailed study could be made relating these two physiological characters.

Another feature which is of pronounced interest was that, in both the present work and that on frost (41), the reaction

was determined using seedling plants. In neither case were there discernible differences in the stage of development when the treatment was commenced. If maturity influences the results obtained there may be either embryonic or protoplasmic differences in development even at this early phase of plant growth. That such differences in maturation may occur is not unlikely, but it is rather difficult to conceive of these rather minor differences playing such an important part in determining seedling resistance. This may be another avenue for future research.

The use of a combined selection program may be an advantage in breeding wheat for drought resistance. From the result obtained for a multiple correlation of the five characters soil drought survival, protein content, maturity, height, and seedling stomatal length, with yield as the dependent character, it can be shown that a considerable proportion of low yielding material might be removed. To assess the value of the multiple correlation Ezekiel (12) used its square as an estimate of the proportion of the variance for the dependent variable which may be accounted for by the removal of the independent variables. Using this criterion 52 per cent of the yield variance was accounted for; this suggests that by making an effort to utilize these variables as implements of selection in early generations, the search for high yielding lines might be narrowed down considerably. Since selection for disease resistance is not considered in the above there would obviously be a substantial reduction in the amount of material left to be carried in

advanced generations.

SUMMARY

Twenty-seven varieties and four hybrid lines of spring wheat were studied in a series of six greenhouse and field experiments. Each experiment was laid out as a Balanced Lattice ($v = p^2 - p + 1 = 31$) which permits of six variety replicates randomized within 31 incomplete blocks.

Three of the greenhouse experiments were set up to determine the relation between seedling leaf stomatal length and soil drought survival. Of these, two were successfully completed, while only stomatal length was recorded for the third one. Highly significant varietal differences were recorded for both characters and there is a significant neg-

ative correlation between them.

Two field trials were conducted, one at Edmonton and one at Swift Current. From both of these experiments data on yield, maturity, height, protein content, and 1000 kernel weight were obtained. The variation in yields of the individual experiments was highly significant but variation in mean yields did not significantly exceed the interaction.

The relation between seedling and flag leaf stomatal lengths was studied in two experiments. In a fourth greenhouse experiment the flag leaves were developed under conditions of extreme soil drought. The yield trial at Swift Current provided the second set of data; the flag leaves here developed under favourable moisture conditions. Significant differences in length were established within each experiment for each of the two leaf levels but the mean flag stomatal lengths were insignificant when tested against the interaction. The genetical relationship between the stomatal lengths of the two leaves appears to have been completely obscured by the influence of environment.

Correlations with yield data from individual trials are hazardous but in the present study they bear out the results of earlier investigations. Yield was positively correlated with soil drought survival, height, and maturity; and negatively correlated with protein content and seedling leaf stomatal length. A partial correlation between yield and survival independent of maturity suggests that the relation between yield and survival, as indicated by the simple correlation, is largely dependent upon differences in maturity.

Soil drought survival and time of maturity are positively correlated.

Protein content is positively correlated with seedling leaf stomatal length and negatively correlated with survival and with 1000 kernel weight.

Maturity may be satisfactorily evaluated from either days to head or days to mature, there is a high positive correlation between them when weather conditions favour normal ripening.

Flag leaf stomatal lengths are influenced by environment to a considerable extent. The flag leaf stomatal lengths of plants grown under favourable conditions were negatively correlated with maturity and soil drought survival, the negative relation with yield approaching significance. The flag leaves of plants grown under arid conditions had stomatal lengths which were positively correlated with maturity, soil drought survival, 1000 kernel weight, and yield. Further work with this character is not warranted.

No advantage was derived from the use of covariance analyses. The data for soil drought survival and flag leaf stomatal length as dependent upon seedling leaf stomatal length were analyzed by this method. In no case did the removal of the proportion of variance due to seedling leaf stomatal length make any appreciable difference in the significance of the dependent variable. Only in one of the four analyses was the residual regression coefficient not significantly different from the variety regression coefficient. In

this one case a significant curvilinear trend was demonstrated for the relation between the seedling and flag leaf stomatal lengths when the latter are produced under dry conditions.

Seedling leaf stomatal length is not significantly influenced by environment and the relation between the results of individual experiments is always reasonably close. This character would be dependable as a basis for selection provided advantageous relationships can be definitely established.

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